

On the linkage between *Anodorhynchus* macaws and palm nuts, and the extinction of the Glaucous Macaw

by Carlos Yamashita & Mauro de Paula Valle

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The genus *Anodorhynchus* is represented by blue macaws with huge heads (Sick *et al.* 1987) and powerful bills. All of them have bare skin around the eye and at the base of the lower mandible (Forshaw 1973, Sick *et al.* 1987). The three recognised species in this group, Hyacinthine Macaw *A. hyacinthinus*, Lear's Macaw *A. leari* and Glaucous Macaw *A. glaucus*, are South American and clearly monophyletic. The first split among them was probably between *hyacinthinus* and *glaucus-leari*. The *glaucus-leari* branch was isolated in marginal, semi-arid eastern habitats, and later differentiated into two forms, the Glaucous Macaw in *chaco* vegetation in the south and Lear's Macaw in *caatinga* vegetation in the north (Vielliard 1979). Considerable doubt attaches to another hypothetical member of the genus, which may have inhabited Guadeloupe in the West Indies, according to accounts by early travellers (Greenway 1967).

This genus of macaws has the strongest "square chisel" on the gnathotheca, the horny part of the lower mandible, among all Psittaciformes. The Hyacinthine and Lear's Macaws use the cutting edge of the chisel as a wedge to split palm nuts in two. Information on these two species, independent of phytogeographical information, suggests that the distribution of the genus is closely linked to palm groves. They are highly specialised macaws, subsisting almost entirely on palm nuts (Sick *et al.* 1987, Munn *et al.* 1987, Yamashita 1987, Brandt & Machado 1990).

The status of the genus today is critical. The Glaucous Macaw is extinct, the other two species endangered. Surveys carried out in the last few years show that Lear's Macaw persists in a tiny population of about 60 individuals (Yamashita 1987, Brandt & Machado 1990), while the population of the Hyacinthine Macaw has been estimated at between 2500 and 5000 individuals, and is declining (Munn *et al.* 1987). The group has suffered from excessive trapping and from the decline of palm groves in the semi-arid region.

The purpose of this paper is to discuss the specialisation of the feeding habit on palm nuts by *Anodorhynchus* and to present arguments about the relationship of the Glaucous Macaw and its process of extinction.

Historical data on the Glaucous Macaw

Comments on the Glaucous Macaw were first published by Sanchez Labrador (1767) who wrote that the *Guaa'-obi* lived along the banks of the Uruguay River, and to a lesser extent, in the forest near the Paraguay River (Castex 1962-63). In the Guarani language of these regions *guaa* is an onomatopoeic name for macaw, and the word *obi* (*hovy*) is a colour gradient from blue to green.

The species was described by Vieillot in 1816, as *Anodorhynchus glaucus*, based on Azara (1805). Vieillot assumed 'Paraguay' as the home of the species, a general name then for a region of southern South America. Azara lived in South America from 1781 to 1801. As an officer of the King of Spain, in order to establish the limits between the territories of Spain and Portugal, he measured the degrees of latitude continuously during his travels. He wrote that the *Guaa'-hovy* was a common bird along the banks of the Parana and Uruguay Rivers between 27° and 29° S, and was told that the species reached 33° S on the Uruguay River (Azara 1805).

There are about seventeen skins of Glaucous Macaw, but only three of them, from the US National Museum, give reasonable mention of provenance. These three specimens were collected during the "Exploration of Parana" by U.S. Navy Expeditions in the 1850s. The labels of these specimens show Corrientes as their provenance. One of the labels also says "Ararana", whereas in the Tupi-Guarani language "arara" refers to 'common macaw'. The Glaucous specimen is thus likely to have been recognised as a distinctive species. The specimens were described as *A. cinereus* in the registration book of the museum. Probably other specimens were collected by that expedition, as indicated by a letter of Cassin to Page (Page 1859). However, there is no specimen in the Philadelphia Academy of Sciences, where Cassin worked, and we do not know the destination of these skins. It is possible that they had gone to the U.S. National Museum, but we do not have concrete evidence. In addition, we could not find reference to Page's "Second Exploration of Parana".

Feeding specialisation of *Anodorhynchus* macaws

Method of study

In order to compare available measurements of the bill apparatus between palm nut specialists and non-specialists, measurements of the chisel width of three *Anodorhynchus* and another 13 species were taken in preserved specimens in the AMNH, USNM, BMNH, MNRJ and MUSP. Palm nuts opened by macaws were collected to illustrate the different pattern of cuts in these two groups.

A satisfactory analysis can be made of the Hyacinthine Macaw's feeding habits. Four species of colonial palms are distributed in the Paraguay basin region: *Copernicia alba* ("Caranda"), *Acrocomia* cf. *aculeata* ("Bocaiuva"), *Scheelea phalerata* ("Acuri") and *Orbignia martiana* ("Babassu"). Measurements of diameter on samples of nuts of these palms were taken and compared with the measurements of chisel width of the Hyacinthine Macaw. *C. alba* and *A. aculeata* nuts (diameters measured on the middle axis) are small in relation to the apparatus of the Hyacinthine Macaw. In the case of *S. phalerata* and *O. martiana* nuts, whose size and shape do not permit the macaws to cut them in the middle, the measurements are taken from the lateral part of the longer axis. This position was defined as a distance of 23 mm from the extremity of *S. phalerata* nuts by Hyacinthine Macaws. The sample of nuts used for analysis consisted of unused nuts, without mesocarp and exocarp, collected randomly in the Paraguay basin.

TABLE 1
Chisel width measurements of macaws and some other parrots

	<i>n</i>	Range (mm)	Mean	s.d.
Non palm-nut specialists				
<i>Ara nobilis</i>	5	6.6–7.8	7.4	0.28
<i>Ara manilata</i>	7	6.8–8.1	7.4	0.28
<i>Ara severa</i>	4	7.2–7.8	7.5	0.23
<i>Ara maracana</i>	7	7.2–8.3	7.7	0.33
<i>Ara auricollis</i>	6	7.6–8.4	7.9	0.15
<i>Cyanoliseus patagonus</i>	2	7.8–8.5	8.1	
<i>Ognorhynchus icterotis</i>	1	9.3	9.3	
<i>Guaruba guarouba</i>	6	9.4–10.8	10.4	0.36
<i>Cyanopsitta spixii</i>	5	7.0–7.6	7.2	0.25
<i>Ara rubrogenys</i>	1	11.6	11.6	
<i>Ara ararauna</i>	14	10.8–11.9	11.3	0.24
<i>Ara macao</i>	16	11.2–13.5	12.2	0.62
<i>Ara chloroptera</i>	14	13.8–17.6	15.4	0.98
Palm-nut specialists				
<i>Anodorhynchus leari</i>	7	19.0–26.8	22.4	2.60
<i>Anodorhynchus glaucus</i>	8	22.0–26.0	24.2	1.40
<i>Anodorhynchus hyacinthinus</i>	10	26.3–32.7	30.6	1.76

Note. In the large macaws, chisel width is not proportional to size. Species of similar weight, e.g. *A. leari*, *A. ararauna* and *A. macao*, can have very different chisel widths; *A. rubrogenys* is smaller than *A. ararauna* but has a wider chisel. Some conures have very wide chisels in proportion to their size.

We also measured the cut-edge diameter of *S. phalerata* and *Syagrus coronata* nuts opened by Hyacinthine Macaw and Lear's Macaw respectively. Using these data we calculated a ratio between chisel size and size of opened nuts, and from this derived a likely value for the diameter of nuts suitable for use by the Glaucous Macaw. We present measurements of *Butia yatay* nuts (probably the main food of Glaucous Macaws) from a cultivated specimen.

Results and discussion

Species of the genus *Anodorhynchus* show the highest value for chisel width among the macaws (Table 1). A comparison of nuts that had been cut by *Anodorhynchus* with nuts cut by *Ara chloroptera* (Fig. 1) well illustrates the difference between the palm-nut specialist and the non-specialist. There is no doubt that *Anodorhynchus* spp. are highly specialised to exploit palm nuts; no other animal can cut a palm nut so cleanly.

However, this group of macaws is highly selective in relation to palm species. Only a small number of palms meet their requirements of size and shape of nuts, and morphology of endosperm, which must be extractable and have a pattern of lignin that permits its use. A feeding habit of this kind, based on only one or a few species, results in a high degree of dependency. Also, in the case of birds as large as *Anodorhynchus*, an



Figure 1. Palm nuts opened transversely by macaws. The nuts on the left were cut crudely by a non palm-nut specialist, the other nuts were all cut with precision by a palm-nut specialist. Left to right: "Bocaiuva" palm (*Acrocomia* c.f. *aculeata*) cut by Red and Green Macaw *Ara chloroptera*, "Acuri" palm (*Scheelea phalerata*) cut cleanly by Hyacinthine Macaw *Anodorhynchus hyacinthinus*, "Licuri" palm (*Syagrus coronata*) cut cleanly by Lear's Macaw *A. leari*.

abundant supply of nuts is essential. This requirement can only be met by colonial palms occurring in dense patches. According to Hauman (1919) the colonial palm species have very special soil requirements.

In the Paraguay basin, Hyacinthine Macaws show a preference for nuts of *S. phalerata* and, to a lesser extent, *A. aculeata*. Figure 2 shows that *S. phalerata* has the most suitable size in relation to chisel size of the macaw; *A. aculeata* is smaller. In this area there are two other colonial palm species which might be used. One of them, *C. alba*, has an unsuitable lignin pattern, while the other, *O. martiana*, has nuts that are too large for the birds to be able to cut. So groves of these two palms are of no importance to Hyacinthine Macaws.

When we compare the chisel width of Hyacinthine and Lear's Macaws with the diameter of the nuts that they exploit, we find a similar relationship between their respective average values. The ratio of chisel width to nut diameter is 1.39 for Lear's and 1.19 for the Hyacinthine Macaw (nut diameter for Lear's Macaw: *Syagrus coronatas*, mean 17.1, range 14.2–20.6 mm; other measurements as in Table 1 and Figure 2). Using the mean of these two ratios we can calculate a nut diameter that should have been suitable for the Glaucous Macaw. The expected diameter would be about 19 mm. There are five colonial palm species in the former range of the Glaucous Macaw: *Copernicia alba* ("Carandai"), *Syagrus [Arecastrum] ramazoffianum* ("Pindo"), *Trithrinax campestris*,

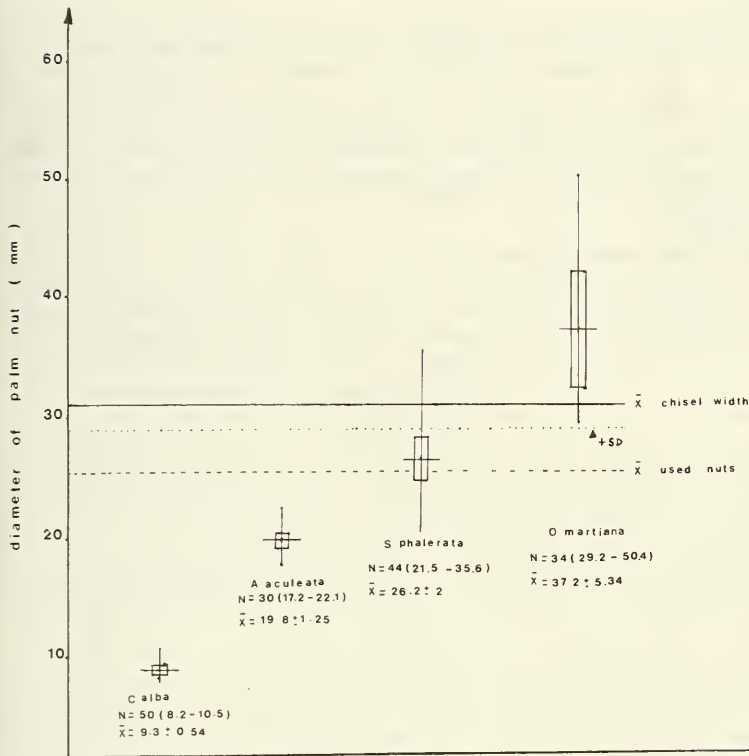


Figure 2. Chisel width of Hyacinthine Macaw, and diameters of random samples of nuts of sympatric colonial palm species in the Paraguay basin. *Copernicia alba* (nuts small, with many vermiculate lignin walls in the endosperm) is not utilised. *Acrocomia* cf. *aculeata* and *Scheelea phalerata* are eaten by Hyacinthine Macaws. Nuts of *Orbignia martiana* are sporadically used; because of their large size, only a very low percentage are available to the macaws (less than 5% in the sample measured). In other parts of the Hyacinthine Macaw's range palm-nut selection is similarly based on nut size and endosperm morphology.

Acrocomia aculeata ("Bocaja") and *Butia yatay* ("Chatay"). The lignin pattern of "Carandai" had been mentioned earlier (see also Fig. 2); it is unsuitable, as also is the lignin pattern of *Trithrinax* and "Pindo" (which on the basis of size would be suitable). "Bocaja" has nuts of suitable size and structure, but only occurs marginally, at the edge of the range of the Glaucous Macaw. The only colonial palm species that has nuts of the right size, with extractable endosperm free of lignin, is the "Chatay" palm; its nuts (from our sample) have a mean diameter of 15.4 mm.

Extinction of the Glaucous Macaw

Labrador (1767) and Azara (1805) agree that the Glaucous Macaw was associated with river-bank cliffs on the Uruguay River. Labrador (1767)

wrote that the "Guaa'-obi" occurred to a lesser extent in forest near the Paraguay River. It is possible that his "Guaa'-obi" refers to the Hyacinthine Macaw at the southern limits of its range in northern Paraguay, where it is rare, and only the bird from the Uruguay River refers to the Glaucous Macaw. Nowadays in Paraguay, "Guaa'-hovy" is a commercial name of Hyacinthine Macaw. Also Sick *et al.* (1987) mention possible identification problems between Hyacinthine and Lear's Macaws, so Labrador (1767) may have used the same name for both species.

Azara (1805) said that the Glaucous Macaw was a common bird between latitudes 27° and 29°S, a very restricted range slightly wider than 200 km. Comparing Azara's data (1923) with current surveying techniques, given the methods used in his day, each latitude could be in error by 0.5°. He was told that the Glaucous Macaw on the Uruguay River reached 33° S, which suggests that he did not personally see it so far south, or that the bird used a very small area there or was locally extinct, because he travelled through almost the entire Viceroy of La Plata (very large portion of South America) during 20 years. We think it quite likely that when the Glaucous Macaw was first reported by naturalists, the relict population was already extremely local and declining.

Original accounts describing the Glaucous Macaw as a very common bird are typical of a naturalist's reaction when encountering a sedentary and conspicuous population of any species of *Anodorynchus*. In some localities *Anodorynchus* are very conspicuous, have a very high site-fidelity, are noisy and travel daily in flocks along predictable flight paths. For instance, biologists observing Lear's Macaw, which now has a very small population, have no difficulty in seeing the birds every day. Likewise when visiting the correct sites, observers perceive Hyacinthine Macaws as very abundant because of their high site-fidelity. Since Hyacinthine and Lear's Macaw specialise on palm nuts, it is very unlikely that Glaucous Macaw did not as well. No doubt the Glaucous Macaw suffered from the same process of palm grove decline as Lear's Macaw is experiencing today (Yamashita 1987, Brandt & Machado 1990). So far we do not know what long-term effect cattle may have on palm groves used by Hyacinthine Macaws. In the Pantanal region, this macaw is commonly seen near the farm houses, which are on higher terrain also favoured by the crucial colonial palms.

The available information on the Glaucous Macaw thus suggests a very restricted range and problems with the decline of palm groves. Its extinction, which seems not to be in doubt, was probably caused by the long-term effect of the introduction of domestic herbivores. It is very well known that in the La Plata region (former range of Glaucous Macaw) palm groves subject to grazing pressure from cows tend to senesce and decline (Hauman 1919, Castellanos & Ragonezi 1949). There has been no palm regeneration in the range of this extinct macaw, and the remnant palm groves are more than 200 years old (Castellanos & Ragonezi 1949).

During his fieldwork at the end of the 18th century, Azara's expedition mainly ate the meat of armadillo and feral cattle. We therefore know that, by that time, feral cattle were already established. Since the European colonisation of the La Plata region, more than 400 years ago, steady

grazing pressure from introduced cattle has decreased the size and health of "Chatay" palm groves and few, if any, new trees have been recruited into the population of reproducing palms. No *Anodorynchus* can survive without healthy palm groves.

Finally, we may suggest a method that may yield additional information. When feeding, all *Anodorynchus* often carry in their beak nuts or pieces of raceme with nuts in order to open them in the top of a big tree or on the side of a cliff. Where these macaws occur, these characteristically severed pieces remain conspicuous for many years. Based on the fact that *Anodorynchus* are such highly specialised feeders on palm nuts, it may be possible to search for evidence of extinct (or hypothetical) *Anodorynchus* in the Caribbean (e.g. *A. purpureus*) by searching for cracked nuts in suitable palm habitats. This may also provide more precise dating for the occurrence of the Glaucous Macaw within its former range, and may enable its range to be defined more exactly.

Summary

Anodorynchus macaws are specialised palm-nut feeders, requiring dense stands of palms. Based on our understanding of the two living species, we believe that the Glaucous Macaw *A. glaucus* was a very specialised species, with a restricted distribution. In particular, we believe that when first reported by naturalists, the relict population was already extremely local and declining. This opinion is based on the relationship between palm-nut size and structure and the macaw's bill size, which indicates that only the "Chatay" palm (*Butia yatay*) could have been the Glaucous Macaw's main food source. The "Chatay" palm groves suffered decline caused by the introduction of cattle, and today they are all senescent.

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On a *Phoebetria* specimen from southern Brazil

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A *Phoebetria* albatross from São Paulo, Brazil (Bertioga beach, 28 August 1954, Museum of Zoology of the University of São Paulo, MZUSP) was identified as *P. palpebrata* by Pinto (1964) and Teixeira *et al.* (1988), the latter doubting our identification (1985, based on a suggestion by R. Grantsau) as *P. fusca*. The 1988 paper also cites a secondary source (Sick 1985), but there is no evidence Sick had identified the specimen himself. Sick overlooked September records of *P. fusca* off the Brazilian coast from 33°22'S, 47°41'W to 28°45'S, 41°02'W (Rumboll & Jehl 1977). *P. palpebrata* is a subantarctic species said to occur in southern Brazil (Vooren & Fernandes 1989), although Rumboll recorded it only at and below the subtropical convergence at 40°–45°S.

After re-examining the MZUSP specimen and others in the British Museum (Natural History) and American Museum of Natural History (New York), we confirm the Bertioga bird as *P. fusca*. It is a dark individual, slightly paler-bodied like all *P. fusca* (see picture in Sinclair 1987; Teixeira *et al.* are incorrect in calling *P. fusca* "entirely sooty brown").

The specimen probably would not have been confused with whitish or ashy-bodied *P. palpebrata* except for certain suggestions in Murphy (1936), some repeated in later field guides. Specifically, we urge caution in using his suggestions of culmen shape (as by Pinto 1964) and about juveniles. Teixeira (pers. comm.) thought the MZUSP bird could not be *P. fusca* because it has a dark orange mandibular stripe rather than the orange one of adult *P. fusca* specimens, yet has pale shafts and dark plumage that Murphy describes as adult.

First, the concave culmen that Murphy shows for *P. palpebrata* is variable and changes with viewing angle; at any rate, we find the culmen of the São Paulo specimen rather straight, contra Pinto (1964). The least central depth of the closed bill is 25.0 mm, above averages of *P. fusca* (24.9 mm, s.d. 0.7; $n=16$) or *P. palpebrata* (23.7 mm, s.d. 1.4; $n=9$). Although these means differ significantly ($t=2.85$, $P<0.005$), recent field guides are probably right to omit this as a field character.

Second, young *Phoebetria fusca* have dusky primary shafts (Richard A. Sloss, *in litt.*; downy birds at AMNH) but, contrary to Murphy (1936)